LAYING AND REPAIRING OF ELECTRIC TELEGRAPH CABLES

CAPTAIN V. HOSKIÆR.

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PREFACE.

Having assisted at or superintended the laying of telegraph cables in the Baltic, North and Japan Seas, &c., and having repaired some other cables, I have written down shortly the experience won in this way, and hereby publish it, hoping it may possibly be of use to some young Telegraph-Engineers.

I have to thank one of the most experienced and able of Telegraph-Engineers, Mr. J. R. France, Manager of the Brazilian Telegraphs, for the very valuable assistance he has kindly given me by revising my manuscript before it got printed.

V. H.

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1. CHOICE OF ROUTE FOR CABLE.

It is always desirable, when possible, to submerge cables in depths beyond the reach of anchors and free from the influence of currents, tidal or otherwise, which might expose the cable to attrition if the bottom is hard and rocky. Depths of over 60 fathoms will in most instances meet both cases.

The depth from which raising for repairs is possible depends entirely on the mechanical construction of the cable, and care must be taken to vary its strength according to the depth it has to cross.

An ordinary iron-sheathed cable, weighing 35 cwt. per nautical mile, cannot be picked up safely from a greater depth than 300 fathoms, even with a large percentage of "slack," whilst a steel-sheathed cable of similar construction has been successfully raised from depths of over 2000 fathoms.

Where practicable, all uneven and rocky bottoms (especially of volcanic formation) should be avoided.

It is also well, if possible, to avoid a bottom composed of substances which attack the cable chemically, or which is

covered with aquatic plants, fungi, corals, and the like, which might destroy the cable.

The landing places should be chosen at spots not used for anchorage, as free from all navigation as possible, and, in Northern latitudes, where there is no drift-ice.

A deep inlet or bay, or between reefs where the bottom is soft and sandy, with the shore free from rocks, is usually chosen for the immersion of a telegraph cable.

Where a cable is payed out from a single vessel, it is more liable to attrition on a hard bottom from the action of the waves and tides near the second landing place than at the starting point, owing to its not being tautened by the steamer as it is in commencing its submergence.

As, however, no foresight can provide against occasional anchorage, in order to reduce this risk of damage as much as possible, it is advisable to have cables varying in weight according to the depths as they increase leaving the shore, so that should a vessel foul it with her anchor, she can slip it again without injuring the conductor or dialectric.

The following table is pretty generally adopted:

Under 20 fathoms	..	10 to 20 tons per naut. mile.	
20 and under 50	..	5 „ 10	„
50 „ 100	..	3 „ 5	„
Over 100	..	1 „ 2	„

When the coast is very rocky in the vicinity of a landing place, more especially if there are strong tides also, a cable can scarcely be made too heavy, either by trebly sheathing it with iron, or at least by a double sheathing, the outer armour being composed of three-strand large wires similar to the latest Atlantic shore-ends.

When the cable has to be laid on a stony beach where it cannot be buried sufficiently deep, it is advisable to protect it by pipes.

Where the cable is laid across sandbanks or quicksands, it becomes often buried so deeply that it cannot at times be recovered without entailing the loss of the buried portion.

During the paying out, the route of the cable ought to be marked down as correctly as possible on a sea-chart.

When no land is in sight, from which bearings can be taken, observations must be made.

2. EXAMINATION OF THE BOTTOM.

In shallow water, soundings are made with the hand and deep-sea leads in ordinary use on board all vessels. A 10-lb. lead, shaped like a shortened cone, is used, and samples of the bottom are brought up on the arming of tallow placed in a cavity in these leads. The sounding line has for every 2–3 fathoms different coloured marks of leather or cloth.

For depths of over 50 fathoms, down to say 500 fathoms, an Albacore line and a much heavier lead (up to 50 lbs.) is used, and the steam winch is brought into requisition for hauling back the line and lead.

For depths still greater than 500 fathoms, Brook's sounding apparatus has been much used, but now Sir W. Thomson's pianoforte-wire sounding apparatus is almost invariably used.

Brook's Sounding Apparatus consists of a rod attached to the end of a line, this rod being connected through a trigger apparatus to a weight of 300 lbs. and more, when the depth

is greater than 1500 fathoms; when the weight strikes the bottom of the sea, the trigger detaches the weight. The line is just strong enough to resist the strain due to the gravity of the weight during submersion opposed to the friction of the water against the line, while on the other hand the line is not strong enough to admit of the weight being hauled up again; accordingly the latter is lost. A body falling freely through the water will descend with uniform velocity after the course of a few seconds. When it is attached to a heavy line, however, the velocity will decrease regularly, owing to the friction of the water against an increasing length of line. The maximum degree of accuracy and expedition in making these soundings is obtained by using the smoothest line and the greatest weight. In using this arrangement the weight is considered as falling freely. It is distinctly observable when the weight reaches the bottom, and the depth can be calculated by the *time of falling*. By this method a more reliable result is attainable, than by measuring the length of the line, as the leeway of the ship, under-currents, &c., may produce considerable curves in the descending line, whereas the time of falling will not be materially altered by these, when the line is a thin one.

Sir W. Thomson's Pianoforte-wire Sounding Apparatus offers much greater facilities than any other known system, owing to the small amount of friction of the thin wire offering very little resistance to the sinking of the sounding weight.

This steel wire is of No. 22 Birmingham wire gauge, and weighs 14½ lbs. per nautical mile in air, which is reduced to 12 lbs. per nautical mile in water; the breaking strain being

between 230 lbs. and 240 lbs., it could support 20 miles of its length in water. The wire is wound on a drum or reel having a circumference of one fathom; to this drum an indicator is attached in order to show the number of revolutions made during the sounding, which will be the depth in fathoms.

A 30-lb. weight, with a small tube and tumbler-catch for bringing up specimens of the bottom, is fastened to the wire. As the weight descends, the brake attached to the drum is loaded with a weight of 10 lbs. at first starting, and on each 250 fathoms being registered on the indicator, this load is increased by a 3-lb. weight counterpoising the weight of the wire run out, leaving the actual pull always at about 20 lbs.

At a depth of 2000 fathoms the striking of the lead on the bottom is very perceptible, indeed quite distinct enough for one to be able to judge whether the bottom is hard or soft.

The wire runs out at the rate of about 12 miles an hour, and can be hauled in by steam at about half that speed, so that a sounding of 2000 fathoms only occupies some thirty minutes, after which the vessel can be under weigh again for her next position.

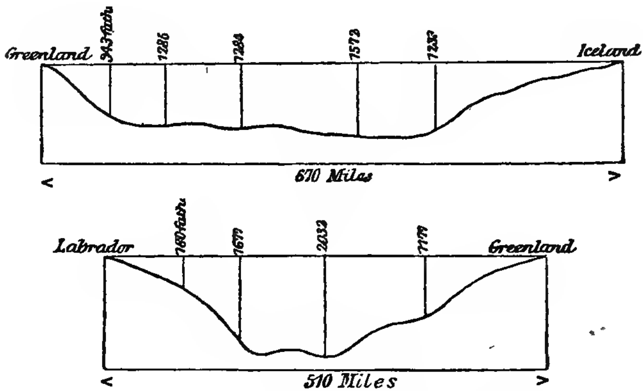
In deep water, preliminary soundings should be taken every 10 knots, if the cable to be laid is not of very great length. Where sudden depressions occur, no pains should be spared to obtain as accurate a knowledge of the inclines and the exact nature of the bottom as possible, which can only be done by frequent soundings.

Even during the submergence of a cable, when the steamer has no consort, approximate soundings of moderate depths

can be taken, allowance being made for the angle at which the wire leads out, which will vary according to the speed of the cable steamer at the time. By this arrangement depths of 150 fathoms have been sounded, while the ship was going at a rate of 6 miles.

For preserving this thin sounding wire from rust, Sir W. Thomson uses caustic soda, the drum and wire being usually immersed in a solution of this, both when in and out of use. In the American navy they use oil for the same purpose with very satisfactory results.

Fig. 1.



The annexed diagram (Fig. 1) shows the profile of the sea bottom between Iceland and Greenland, and Greenland and Labrador. To present the exact relative depths, however, these diagrams would have to be lengthened fifty times.

It is also essential to become acquainted with the winds, tides, ice-drifts, &c., &c., at different seasons of the year, in order to take advantage of the finest weather for laying the cable.

3. LENGTH OF THE CABLE.

After the route of the cable has been determined on, and thoroughly surveyed, it should be set off on a chart of as large a scale as can be procured, and the distance correctly calculated for each type of cable.

According to circumstances a percentage varying from 5 to 20 per cent. is added, partly for slack, and to ensure a sufficiency to reach between the points chosen, and partly in order to leave some surplus cable for present contingencies and future repairs and maintenance.

When in a known time n knots of cable have been payed out, while the ship has been sailing at a rate of m knots, then the slack payed out will be $\frac{n-m}{m} \cdot 100\%$.

The slack of the Atlantic cable was 9 per cent., and with some other deep-sea cables it has exceeded 15 per cent. and even more. The pitching of the ship does not appear to cause any sensible increase of slack. It is desirable indeed, to have as little slack as possible, partly to save cable, and partly to have a shorter distance to work through; but to provide for the lifting of the cable at repairs, it is necessary to allow sufficient slack during the paying out.

4. TELEGRAPH STEAMERS.

A steamer employed in submerging cables should be specially built for the purpose, as it is then possible to make provision for almost any casualty that may arise by everything being properly adapted for the purpose it has to serve. The 'Faraday' and 'Hooper' are vessels of this class.

Often, however, from force of circumstances, steamers

employed in commerce have to be transformed into cable ships, and many shifts made in order to make them at all suitable for the new purpose for which they are destined.

The first consideration is to carry all the deep-sea section in a single bottom. The object of this is to avoid splicing the cable in deep water to that in a second vessel, always a delicate and sometimes a hazardous proceeding.

She should invariably be ballasted by water in several compartments, in order that as she becomes lightened by the cable payed out, she can be kept on a nearly even keel. The bunkers must have sufficient capacity to carry coal enough to complete the laying, and her engines sufficient power to steam 9 or 10 knots in a calm, so that in the event of meeting with heavy weather there will be a probability of her being able to forge ahead at some 4 or 5 knots at least.

During the laying of a cable the steamer's compasses are often affected by the varying quantities of iron on board, the deviation at times being considerable.

For this reason alone, *irrespective of the important assistance she could render otherwise in case of an accident occurring, it is advisable to have a consort to act as pilot in running the courses determined on during the paying out of the cable.*

Many devices, as Wier's pneumatic apparatus, a gong, &c., have been adopted for telegraphing orders from the tanks, &c., to the ship engineers, but scarcely any proved effective. The surest method is to place a trustworthy man in view of the officer in charge of the bridge, and a quartermaster with his hand on the engine room telegraph, the engineers having instruction to reverse at full speed on the first alarm, and then afterwards to follow the order given on their telegraph.

It is usual to station *repairing-steamers* on the more distant and sometimes on the home stations; these of course are of smaller capacity, and should also be built specially for the work, as so many devices for the saving of labour and time can be turned to account in a new vessel.

The repairing-steamers ought to be provided with at least three tanks, a single set of machinery for paying out and picking up, watertight compartments for taking in water-ballast, and a covered engine room.

The 'Lady Carmichael' and 'H. C. Oersted' are steamers of this class.

The *chart room* should have as good an all-round view as can be obtained, so that angles and bearings can be immediately marked off by the officer taking them.

There should be ample *store room* under lock and keys for keeping tools and materials in readiness for immediate use if required.

In hot climates the hulls of cable steamers should be painted a light colour, as the temperature of the hold is thereby lowered some 5° or 6° Fahr., which is of immense importance to the future of the dielectric. Sailors as a rule have a strong objection to any colour but black for a hull, but when such heavy interests are at stake this should be insisted on.

5. MACHINERY.

The machinery of cable ships generally consists of a paying-out machine at the stern, and a picking-up machine at the bow. The picking-up machine ought to have its own separate steam-engine, and it would be an advantage if the

paying-out machine had its own engine too, that it might be used for picking up the cable when wanted. The whole machinery should be of the most plain and solid construction, secured as well as possible against any accident.

In the sequel will be given a short description of all the separate parts of the paying-out machinery from the tank to the stern pulley, where the cable leaves the ship. The picking-up machinery consists of similar parts.

6. TANKS.

A telegraph cable must always be kept under water for the purpose of preserving the dielectric, and also in order to detect the slightest failing in its electrical condition.

To be enabled to do this on board ship it is coiled into iron watertight tanks, the plates of which are riveted or bolted together.

In cable-laying steamers the tanks should be few, in repairing-steamers as many as possible.

In the centre of the tank a cone is built, either a watertight iron one, or a mere framework of wood. The latter occasions the carriage of so much extra water, but has the advantage of allowing of the cutting of a cable without its removal, should a fault show itself.

The object of the cone is to keep the running coil clear, and prevent its turning over, which would kink the cable.

Means are provided for filling each tank with water, and also for pumping it out.

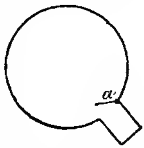
The cable is coiled into the tanks from the outside towards the eye. In paying out it uncoils from the eye towards the outside, and in order to obtain a straight pull to

the cone a large iron ring, generally made of gas-pipe, is suspended and stayed at about 18 inches from the working flake; this ring is lowered as the tank is emptied. With deep tanks two or more shifting rings are used.

Over the eye of the coil and above the cone a smaller ring is fixed for controlling the cable, which would without these rings fly about by centrifugal force if the cable were going out at any speed, or the steamer rolling.

To keep the end that was left out for splicing from one tank to another, clear from the cable, that is running out, a recess is made in each ring, (Fig. 2) the bottom end is passed through all the rings and secured in these recesses by a hinged piece *a*, which is fastened by means of a bolt from the outside of the ring, so as to leave an even surface inside. It is kept in these recesses until it is necessary to change the paying out to another tank.

Fig. 2.



7. JOCKEY GEAR.

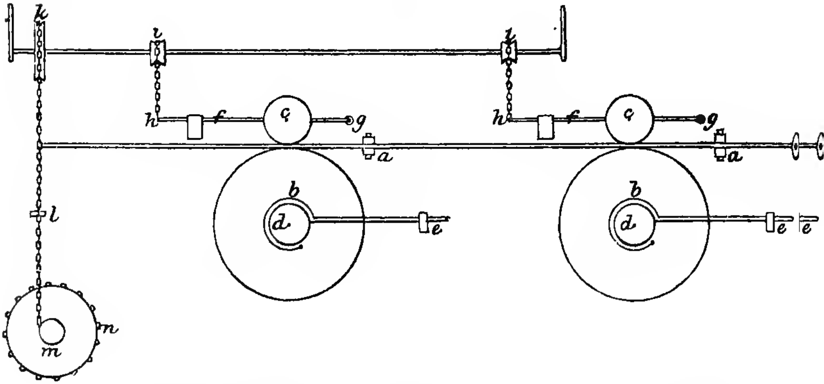
From the upper ring the running cable usually passes over an iron quadrant into a trough, which leads in as direct a line as is possible to the jockey gear.

In the trough the cable passes over a number of rollers about 10 feet apart from one another.

The friction of the quadrant and in the trough tends to straighten the cable before it reaches the roller *a*, Fig. 3; it then passes into a grooved wheel *b*, to which a brake is attached, the pressure of which is controlled by a movable weight *e* on the lever. The brake wheel *d* is partly immersed in running water to keep it cool.

The jockey or riding wheel *c* presses the cable into the groove of the wheel *b*, the pressure being regulated by means of a movable weight *f* on the lever, whose fulcrum is at *g*.

Fig. 3.



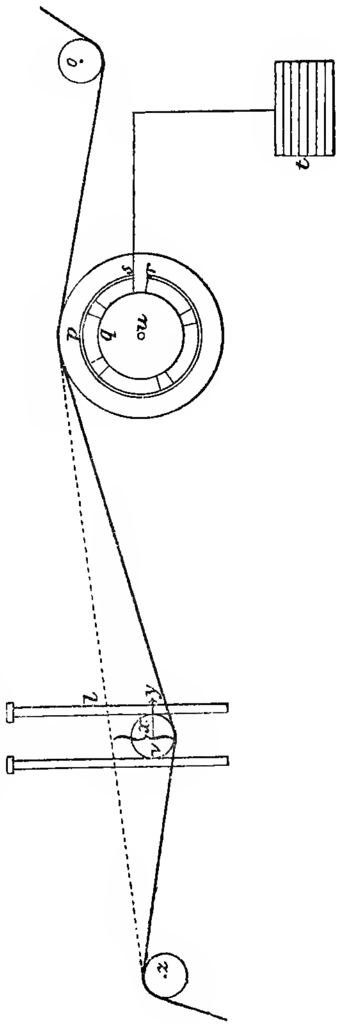
From one jockey the cable passes to another, and in deep water four or five jockeys are used for holding back the cable, so as to make it bite on the paying-out drum.

As it is sometimes important to be able to ease the weight of the jockeys instantaneously, each jockey lever-end is attached by a chain to a single shaft that can be turned by the man on watch by means of a steering wheel *m*. The whole of the jockeys can thus be lifted at one operation.

With a cable running out at a high speed, say 6 knots, the least unevenness would cause the jockeys to jump, and to fall back on the cable with force. In order to lessen this the riding wheels *c* are usually tyred with vulcanized indiarubber. Every precaution is taken to remove the mile or other marks from the cable before it passes from the tank to the jockeys.

8. BRAKE GEAR.

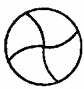
Fig. 4.



From the jockey gear the cable passes to a fairlead *o* (Fig. 4), and then three or four times round an overhanging drum, which is usually about 18 feet broad and 3 fathoms in circumference.

On the shaft of this paying-out drum are two brake wheels (Fig. 5), the arms of which should be curved to allow for expansion. These brake wheels are about a foot broad; against them a series of blocks of wood are pressed to cause friction. The blocks of wood are attached to a strong iron strap *p*, one end of which is rigidly fast at *r*, and the other end *s* attached to the lever in such a manner as to give a leverage of about 7 or 8 to 1. At the end of this lever a rod is suspended; the rod has a platform on which weights (of *c* 30 lbs. each) are added as extra friction is required for increasing the brake power.

Fig. 5.



The brake gear is always, when in use, kept partly immersed in running water.

9. INDICATOR.

A revolution indicator or counter is attached to the shaft of the paying-out drum. The diameter of the different types of cable causes a slight variation in the number of revolutions to the mile. It is only necessary to add the circumference of the cable to the circumference of the drum to get the exact length of a revolution.

The drum on the 'Africa' was not quite 3 fathoms in circumference. The following table shows the ratio between the number of revolutions and the different types of cable payed out from that vessel, when laying the G. N. T. Co.'s cable between Wladiwostock and Nagasaki.

347·8	revolutions	=	1 naut. m.	of cable of	1·8	tons.
346·7	„	=	„	„	3·1	„
344·8	„	=	„	„	7·0	„

10. DYNAMOMETER.

From the paying-out drum the cable is led to a dynamometer; it passes over two wheels at fixed points *p* and *z*, (Fig. 4) one of which, if the steamer is a short one, may be replaced by the drum itself; but there are usually two grooved wheels, midway (as nearly as possible) between which stationary points a third grooved wheel is so fitted to pneumatic gear that it can freely travel up and down, being controlled by a plunger or piston in a cylinder containing

water or oil, which acts as a buffer to prevent the sudden falling of such a heavy weight, as this wheel and its accompanying gear must necessarily be.

On a paying-out dynamometer these weigh seldom less than 2 cwt., whilst on a picking-up dynamometer, for deep-sea work, where heavy strains have to be indicated, the riding wheel, carriage, and piston often weigh over a ton.

The scale of the paying-out dynamometer should be graduated to indicate from the minimum strain at which the cable is to be payed out to the maximum strain the cable will bear up to breaking point.

Of course the engineer gives instructions as to the amount of strain to be allowed under ordinary circumstances. The scale of a paying-out dynamometer usually ranges between 5 and 150 cwts.

If the distance between the two stationary wheels (two fixed joints) p and z be $= l$ and the travelling weight be $= v$; let this weight depress the cable through a height x, then the strain on the cable is:

$$= \frac{v \cdot \sqrt{\frac{l^2}{4} + x^2}}{2\,x}.$$

Sometimes the scale is determined by applying actual weights; this is scarcely necessary, the formula giving correct results within a small fraction.

Dynamometers with springs have been used, but in general practice weights can be more relied on.

From the dynamometer the cable passes over the stern sheave, and sinks to its future resting place as the steamer follows the track marked on the charts.

Provision is made on the girders carrying the stern sheave for holding or stopping the cable, should it require it, for changing tanks, heated bearings, &c., or, in case of accident, for transferring the cable itself from the stern to the bows of the steamer.

In former times the steamer's screw was guarded by a framework of iron attached to the vessel's stern, in order to prevent the cable fouling the screw, but these "crinolines" were found to be sources of danger to the steamers, and were therefore abandoned.

11. TESTING-ROOM.

As the instruments employed to show the electrical condition of the cable are mounted so as to be exceedingly sensitive, it is essential the testing-room be placed as near amidships as practicable, as that is the position of the least movement. Lamps are continually burning in the testing-room, therefore every precaution must be taken in the way of ventilation. Great care must be exercised that no leakage occurs, as it might damage the instruments and render them useless. The space should be at least 20 square yards, and as large as is possible to spare room for a quantity of different instruments, batteries, &c., &c., being kept in constant readiness.

12. COILING ON BOARD.

The process of coiling the cable into the tanks is carried out thus:

A length of about 40 fathoms is first left out for splicing on to any of the other tanks that may be decided on. The cable is then led to the bottom of the tank, and the coiling is commenced from the outside, and continued until the flake reaches the cone; it is then led back right across the flake to the outside of the tank. This is repeated until the whole length destined for the tank is coiled into it.

With compounded cables every flake is whitewashed, to prevent sticking.

At every mile a punched leather ticket is attached, showing the number of the mile. These tickets are placed in a straight line fore and aft of the steamer, so as to be easily found and detached in the tank before the cable passes out to the jockey gear.

The positions of all core joints are also marked by red paint, on the outside of the cable.

Water is run into the tank as the cable is coiled away, and kept to the level of the working flake.

It is usual to put some distinguishing mark, such as a large strip of canvas or oilcloth, on the second flake from the bottom, not so much as a matter of necessity as to call the cablemen's attention that the time for changing tanks is drawing near.

The hauling-in machine, either by jockey or drum, is made to indicate the exact length of the cable delivered on board, the cable being coiled once or more times round the

indicator wheel. These lengths are noted, together with the number of the flake, of turns in the flake, of mile-marks, as well as the exact position in the tank of every factory splice and core joint.

Too great care and attention cannot be bestowed on the coiling.

Appendices I. and II. show the regulations and logs for coiling the Great Northern Telegraph Co.'s cables.

The coiling away being completed, the cable is thoroughly tested from the shore for insulation, inductive capacity, and conductivity. If it has to be sent a long distance, the tank is decked over.

13. LANDING SHORE-END.

The landing of a shore-end has to be conducted in different ways, according to the boldness of the coast, and the weight of the cable that has to reach the cable house from the steamer's anchorage.

Sometimes a ship's boats suffice, at others a steam-launch is used, one or more rafts have to be improvised by lashing two boats, or some empty casks, or some indiarubber bags, or some iron caissons (to ex. 10 feet long, 4 feet broad, and 3 feet high) together, and temporarily planking them over. Even a single block has been made fast on the shore and a rope rove through it, when the cable has been hauled to the land by the steam machinery on the steamer.

In northern latitudes it is necessary to take precautions against injury to the shore-end from drift-ice, which is usually done by laying it between two rows of strong poles, reaching from high-water mark to a distance below low-water mark

equal to the maximum depth of the drift, when the ice breaks up, and protecting the poles by filling stones up around them. The cable is sometimes further protected by iron piping.

From low water to the cable-house it should, where possible, be buried in a trench 3 feet deep.

The landing being successfully completed and the shore-end securely made fast enough to hold it whilst the cable steamer is starting, the anchor is weighed, and on receiving notice from the electrician that his tests show all is in perfect order, the word for the ship's engines to "go ahead slowly" is given, and the paying out commences.

14. CHANGING TANKS WHILST PAYING OUT.

The operation of changing the paying out from one tank to another is carried out thus:

When about a mile from the bight (it has been treated as bottom end up to now, but since it has been spliced on to another tank it has become a bight) run up in the recesses of the tank rings, all available hands are called on deck, each man being posted and instructed what he is to do.

The steamer is gradually slowed down and eventually stopped, the weight is taken off the brake at the drum, to prevent the ship from riding too heavily on the cable. When there are but ten turns of cable left in the tank the recesses in the rings are opened and the cable freed; by the time the last turn of the bight is the only one left in the tank (a second turn would foul) the way of the ship is usually stopped, or so nearly so, that either the cable is laid into the trough leading to the fresh tank, or, if the vessel is

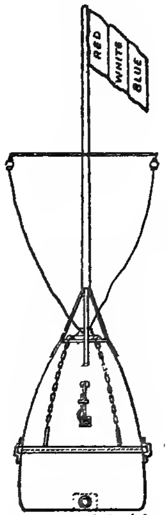
stopped dead, this last turn is hauled out and coiled on the top of the fresh tank.

All being in order, the word is given to "go ahead" again.

15. BUOYING.

Provision has to be made for accidents whilst paying out: such as fouling in the tank, alteration in electrical condition, &c., &c., and there may be occasion to buoy the cable.

FIG. 6.



Buoy 7·3″×5·8′
2 Tons displacement to Deck.

In deep water the buoy is generally made fast to the telegraph cable alone.

In shallow water a stray chain is first secured to the cable and shackled on the moorings close to the mushroom anchor.

This shape of anchor is chosen for its handiness, and as being less liable to get foul than any other form; next to this is always chain, but for deep water very little chain is used next to the mushroom anchor; the remainder of the length requisite to reach the surface being composed of one of the different forms of wire rope, or of coir rope.

The buoys are of different shapes (named "onion buoys," "nun buoys," "pear buoys," &c.) and of different sizes to float the moorings requisite for deep water. The buoys (Fig. 6) are made of iron plates, and may have by a depth of 300 fathoms a height of 8 feet, a diameter of

5 feet, and a floating power of about 2 tons; the largest size being capable of floating 7 tons at its load-line.

The flag used may be the universal telegraph flag or any other flag; at night-time lamps are attached to the flag-staffs as a mark for the steamer.

Fig. 7.

Holmes' lights, which burn for an hour, are extremely useful at night-time, as when thrown overboard they enable the steamer to keep on the spot until a buoy can be let go.

Fig. 7 shows the mode of attaching and detaching a buoy.

The riding chain *a* is made fast either to the telegraph cable or to the other moorings, as the case may be; it is rove through the toe ring *b* of the buoy, and then on to a tumbling-catch at *c*, where it is secured.

To the shackle at the point *d*, which is usually 5 fathoms under water, a strong chain *e* is attached, which is made fast to the buoy at *f*.

16. PICKING UP.

When it is requisite to unmoor a buoy the steamer goes stem on close to it, and a boat is lowered, whose crew, after having taken the flag and flag-staff from the buoy, shackle a warp running from the steamer on to the chain *e*, attaching a second rope from the steamer to the place where the chain *e* was freed from.

They next clear the trigger of the tumbling-catch at *c*,

when the riding chain, by its own weight and that of the moorings, runs through the toe ring, and the buoy is clear for being hauled alongside and replaced in position for future use.

The chain *e* is then led to the picking-up cable machinery, which is simply a very large steam winch of enormous power, in some cases capable of exerting a steady pull on the periphery of the drum equal to 30 tons.

To work under such strain the speed is necessarily slow, but there is usually a second and sometimes a third speed, enabling the drum to be worked much quicker when the strains are reduced.

During the process of hauling in a cable from deep water, it is subject to a much higher strain than during manufacture or paying out, and the then indicated length is sometimes as much as 3 per cent. in excess of the previously recorded lengths.

The brakes for the picking-up machinery are worked with screw gearing, as they have to clutch the drum in order to hold the immense weights that have at times to be dealt with.

A revolution indicator is attached to the drum shaft.

The paying-out drum and the picking-up drum should be in a line with each other, so that when desirable to work from the stern it can be done with the powerful machinery forward.

In order to keep the rope tight and make it bite the picking-up drum to prevent its slipping, a jockey arrangement is added, worked by gearing from the cable engine; the grooved wheel, in which the rope is laid under the jockey,

travelling at a speed slightly in excess of that of the drum itself.

17. REPAIRS.

It is sometimes necessary after submergence to bring the cable to the surface for repairs.

When a fault or breakage has been localized by the electrician, the steamer proceeds to the position where a mark buoy is ordinarily moored for the vessel to work by.

A grapnel with five prongs or arms, and weighing about 2 cwt., is payed overboard with sufficient ground chain to take the chafe of the bottom and keep the grapnel shank in a horizontal position; these are shackled to either an iron or hempen rope, according to the depth and nature of the bottom, together with the strain likely to be put on it.

The rope after passing the dynamometer is passed several times round the picking-up drum.

The vessel steams gently ahead, at a rate of from 1 to 2 knots an hour, across the line of cable, at right angles, until by the increase of strain indicated on the dynamometer scale it is shown the cable is hooked.

The picking-up machinery is then put in motion and the bight brought to the surface.

The cable is now cut at the bows, and an insulated wire run from its core to the testing room, for the electrician to decide which side is to be buoyed.

After buoying one end the other is led round the drum (still keeping it under the dynamometer), and the cable picked up and coiled away into one of the tanks until the fault is cut out; or if a broken end is reached a second mark buoy is immediately dropped, and the other broken end

sought for in a similar manner to the first bight brought to the surface.

The insertion of a new piece is usually carried out entirely from the bows of the steamer, more especially if the distance is short, thus avoiding the transference from bows to stern, and *vice versâ*, which is often very risky when the ship is unsteady in the sea.

During the splicing an anchor or mushroom might be put out forward to prevent the ship from riding too heavily on the cable, and care should be taken that the screw does not catch the cable, and that the cable does not kink by the swinging of the ship. When the splice has been finished and the cable is found in order, the bight is slipped over the bow, while the ship is backing. To have the bight paid out as tightly as possible and without kinking, it is controlled by means of two thin lines affixed at the end of it, about 3 feet apart, which are cut with an axe the moment the bight has sunk below the surface.

When the picked-up end has not been well sealed, the sea-water will sometimes penetrate so far into the conductor, that it may be necessary to cut out a considerable length of core before making the joint. To prevent the water from penetrating still farther into the cable while this is hauled in—which is likely to happen by an old cable of Hooper's Core, where the conductor sometimes lies loose in the core—it will be necessary to seal the picked-up end before more cable is hauled in.

The cable has sometimes to be *underrun*, in a small depth of say within 7 fathoms, by a cable of 1½ ton, and in fine weather this may be done by putting the cable

over a boat in the direction of its length, while the crew advances the boat by hauling the cable. To provide against capsizing by a strong current, it may become necessary to put the cable across the boat, but it is still better to lash two boats together with wooden beams, suspend fair-leads in these beams, and underrun the cable hanging in these fair-leads between the boats.

In the open sea, by great depths and by a considerable length of the cable, the under-running is performed by passing the cable over an under-running sheave suspended from the bow of the ship, while the ship proceeds slowly over the track of the cable.

18. TESTING BEFORE SUBMERGENCE.

Before coiling the cable on board the ship, a complete series of very careful tests should be made on shore; the copper-resistance, inductive capacity, and insulation of the cable being determined as correctly as possible. At the insulation test the cable is connected for fifteen minutes to the copper-pole of the battery, and for other fifteen minutes to the zinc-pole, the deflection being read off every minute.

During the coiling the cable must be subject to continuous tests for insulation and conductivity. These tests are made on shore, as much more delicate and sensitive instruments can be employed there than on board ship. The beam of light on the scale of the galvanometer is watched continually, or a bell is made to ring, or some other ingenious device is employed for giving an alarm, if a want of continuity occurs to the conductor.

After the coiling the copper resistance and insulation of the cable is determined by tests every day. On the voyage to the place where the cable has to be paid out, tests are taken every day to determine the copper resistance and insulation.

During the voyage great care must be taken always to keep the cable under water, and by loading the ship, the weight of the water ought to be taken into account. Except in cases of *force majeure*, the water should never be drawn from the tanks on a voyage except for the purpose of changing the water itself. Sometimes also the water outside the steamer is of a lower temperature than that in the tanks; it is then advisable to pump a foot or two out and let in the fresh, and continue doing so until the temperature in the tank is equal to the temperature of the sea.

To have means of determining the temperature of the cable at different heights of the tank, Mr. Siemens has proposed to put a small coil of copper wire between the flakes; the resistance of this coil at 75° Fahr. being exactly known, the existing temperature may be calculated by determining the actual resistance of the coil. Mr. Siemens' coil consists of silk-spun copper wire wound upon an 18-inch long iron rod, the whole coated with indiarubber, and cased in a metallic cylinder.

Shortly before paying out, a complete series of tests is taken, in the same way as before the coiling of the cable.

The daily tests are recorded according to the form, Appendix III.; the results of these tests entered according to the form, Appendix IV.

19. TESTING DURING SUBMERGENCE.

Having treated of the testing applied *during submergence* in my 'Electric Testing of Telegraph Cables,' it is not necessary for me to recapitulate here.

20. TESTS AFTER SUBMERGENCE.

After laying of the cable a similar series of tests is taken as before the same, and at the time when the cable has to be handed over by the contractor to the company, the engineers of both parties in conjunction test the cable, to ascertain whether it is in accordance with the specification.

When a fault occurs in a cable after it has been laid, and the fault is great enough to make it likely that the position of it may be localized, it will be necessary to know the copper-resistance per knot of the faultless cable, otherwise a correct determination of the fault is impossible.

Copper-resistance increases as the temperature rises, and to be enabled to ascertain correctly the actual resistance corresponding to the temperature of the conductor, it is desirable that frequent tests should be taken from each terminal station. On the cables of "The Great Northern Telegraph Company" these tests are made according to the annexed 'Instructions to Electricians' (App. V. and following six appendices).

21. RECORDS KEPT DURING PAYING OUT.

From the moment a cable steamer leaves the factory until the cable itself is actually submerged, a record of everything occurring on board should be kept, even to trifling matters which at other times might be allowed to

pass without notice. The entry might possibly prove of service although at the time there may appear but little probability of its ever being of use.

Besides the record of ordinary everyday occurrences during the laying, there are special logs to be kept in the engineering, electrician, and navigation department.

While the cable is being payed out, one of the engineering staff has always to be on deck. He watches the indicator and the dynamometer, and notes down in the log-book the number of revolutions of the drum per minute, the total number of revolutions for every full hour, the strain indicated by the dynamometer, the number of revolutions of the screw per minute, &c.

A note-book of the form given in Appendix VI. may be used during the paying out, and the results entered every hour in a journal of the form given in Appendix VII. In a second journal entries are made of the electrical tests, the correspondence with the shore station, the temperatures of the air, tanks, and water, and everything affecting the electrical condition of the cable.

22. STRAIN ON CABLE BY PICKING UP.

The strain on the grapnel rope may be calculated in the following way: Let T (Fig. 8) be the strain on the grapnel, and t the strain on the cable, when raised through the height h from the bottom; let $2\,k$ be the length of the cable raised, $2\,x$ the horizontal projection, and v the weight in water of 1 foot of cable. Then:

$$k = \sqrt{x^2 + h^2} \text{ or } \frac{k}{x} = \sqrt{1 + \frac{h^2}{x^2}} \qquad (1)$$

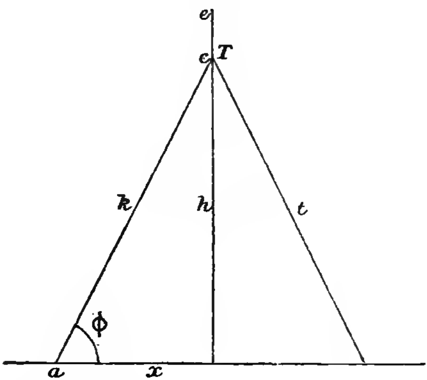
Let q be the slack of the cable in proportion to the length paid out. Then:

$$q = \frac{k}{x} - 1 \ldots (\text{thus with } 10\% \text{ of slack: } q = \tfrac{110}{100} - 1 = 0 \cdot 1)$$

or
$$q + 1 = \frac{k}{x} \qquad (2)$$

and
$$k = (q + 1)\, x \qquad (3)$$

FIG. 8.



From (1) and (2) we get: $q^2 + 2q = \frac{h^2}{x^2}$, whence $x = \frac{h}{\sqrt{q^2 + 2q}}$ and by substituting the value of x in (3),

$$k = \frac{q + 1}{\sqrt{q^2 + 2q}} \cdot h$$

Consequently:

The strain on the grapnel—

$$T = 2vk = 2vh \cdot \frac{1 + q}{\sqrt{q^2 + 2q}}$$

The strain on the cable—

$$t = \frac{\mathrm{T}}{2\ \sin.\ \phi} = \frac{v\,k}{{}^{h}/_{k}} = \frac{v\,k^2}{h} = v\,h \,.\, \frac{(1+q)^2}{q^2+2q}$$

When the cable is allowed to slide freely along the bottom without being fixed at a, the slack q may be put $= \infty$, i.e. infinitely great, which makes $\mathrm{T} = 2\ v\,h$ and $t = v\,h$.

If on the contrary, the cable were fixed at a, T and t would exceed $2\,v\,h\ \dfrac{1+q}{\sqrt{q^2+2q}}$ and $v\,h\ \dfrac{(1+q)^2}{q^2+2q}$, which values accordingly lie between the two limits for the strain.

When a cable has been payed out with say 10 per cent. of slack, or $q = 0{\cdot}1$, then $\mathrm{T} = 2\ v\,h\ 2{\cdot}4 = 4{\cdot}8\ v\,h$ and $t = 5{\cdot}76\,v\,h$. Let 1000 fathoms of the cable have a weight in water of 1 ton, and let the cable be raised 100 fathoms from the bottom, then the grapnel rope $c\,e$ will have to lift $4{\cdot}8 \times 100 \times \frac{1}{1000}$ ton $= 0{\cdot}48$ ton, making the strain on the cable $= \dfrac{0{\cdot}48}{2\ \sin.\ \phi} = \dfrac{0{\cdot}48}{2 \cdot \frac{1}{24}} = 5{\cdot}76$. To which must be added the strain due to the friction of the water against the surface of the cable, to the resistance of the water against displacement, and to the increased length of cable, which is owing to the fact that the cable hangs in a catenary curve, and not in a straight line, as was assumed. The strain may also be increased by pitching of the ship.

If the weight of the cable is 1 ton per knot, or the weight v in water = about $0{\cdot}001$ ton, and if the cable is raised from the bottom through the height h, then:

with the slack $q =$	1%	2%	5%	10%
The strain on the grapnel T is	$0{\cdot}0142.h$	$0{\cdot}0102.h$	$0{\cdot}0064.h$	$0{\cdot}0048.h$
The strain on the cable t is ..	$0{\cdot}0504.h$	$0{\cdot}0260.h$	$0{\cdot}0102.h$	$0{\cdot}0058.h$

Suppose a cable weighing 3 tons, and having been payed out with only 2 per cent. of slack, has to be raised from a depth of 100 fathoms, then, according to the table, the strain on the grapnel will be $= 3 \times 100 \times 0 \cdot 0102 = 3$ tons.

23. MODULUS OF TENACITY.

The length of cable hanging vertically in water which the cable itself is able to carry before breaking is called the *modulus of tenacity* of the cable.

In practice it is considered quite safe to lay the cable in a depth = one-third modulus, which makes the strain = one-third of the breaking strain. But as the strain may be accidentally increased by the friction of the paying-out machinery and by the pitching of the ship in stormy weather, and as furthermore the strain when the cable has to be picked up, is many times greater than during the laying, even though there be sufficient slack, it is not advisable to lay the cable in a depth exceeding oue-tenth of the modulus.

A cable of great strength and small specific gravity is most to be recommended.

The strength of the cable depends upon the dimensions of the iron covering far more than upon the core, which will be seen from the following table:

	Breaking Weight per Square Inch.	Weight of 1000 feet of 1 square inch Sectional Area.	Specific Gravity.	Weight in Water of 1000 feet with 1 square inch Sectional Area.	The Modulus.
	lbs.	lbs.		lbs.	
Iron ..	56,000	3340	7·7	2900	19,000′
Copper	34,000	3820	8·8	3380	10,000′

Taking one-tenth of the modulus as the maximum depth, according to the above table, this depth will be 1900′ = about 300 fathoms. Steel-covered cables may be laid safely at depths two or three times greater, the breaking weight of steel being at least 124,000 lbs.

Attempts have been made to increase the strength of the core either by winding the copper wire with steel wire (Allan), or by substituting $2\frac{1}{2}'''$ iron wire and $1'''$ gutta-percha (Blavier) for $\frac{1}{2}'''$ copper wire and $2'''$ guttapercha. From mechanical reasons, however, these attempts have hitherto proved failures.

The specific gravity of the cable is generally diminished by increasing the amount of hemp, the specific gravity of dry and white hemp being 0·66 (its breaking strain = 6000 lbs. per □″) and of moist and tarred hemp 0·92 (breaking strain = 3300 lbs. per □″).

The strength of the cable is probably not materially increased by using a large amount of hemp, although trials with hemp-covered iron wire seem to prove that the breaking strain of the cable may be considered equal to that of the hemp and iron combined.

An increased amount of hemp, however, gives the cable a smaller specific gravity and a larger volume, thereby diminishing the strain during the submersion, and causing the cable to sink slower by being exposed to a greater resistance of the water, which resistance is further increased if the surface of the cable is rough.

The specific gravity of the cable varies with the quantities which are used of the following materials :—

Indiarubber having a specific gravity of			1·176
Guttapercha	,,	,,	0·975
Pitch	,,	,,	1·65
Tar	,,	,,	1·02
Silicate	,,	,,	1·76

The specific gravity of the China-Japan main cable is 2·65.

24. THE ANGLE OF IMMERSION.

A cable weighing v lbs. per foot in water, and in air v' will sink vertically in water with a *velocity* h determined by:

$$v = c\, h^2 \text{ or } v' = c'\, h^2.$$

The constants c and c' depend upon the resistance of the water against displacement, and the friction of the water against the surface of the cable. This friction may increase to 80 lbs. per knot, and will tend to untwine the cable unless the iron wires are sewed with hemp and compound.

The weight in air v' of the China-Japan main cable is 0·644 lbs. per foot (1·75 tons per knot). Thus taking 0·14 as the constant, we shall have $0 \cdot 644 = 0 \cdot 14\, h^2$.

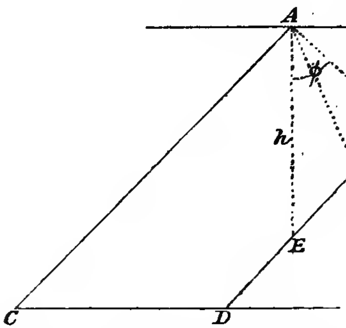
$$h = 2 \cdot 15 \text{ foot.}$$

The velocity of sinking may be calculated in another way.

Let the ship move with an uniform speed h' from A to B (Fig. 9) in one second, while the cable C A moves to D B; call the angle which the cable forms with the surface ϕ, and the velocity of sinking A E = h. If B F be the velocity with which the cable is payed out, the point A of the cable has actually not reached to E but only to F.

The velocity of the cable in a direction perpendicular to its length is A G $= h' \sin. \phi$. The resistance of the water at right angles to the cable is per foot $= c\, d\, h'^2 \sin.^2 \phi$; d being the diameter of the cable. This resistance is further

FIG. 9.



equal to the component perpendicular on the cable of the weight in water of 1 foot of cable. If this weight is v, this component will be : $v \cos. \phi$, accordingly :

$$v \cos. \phi = c . d . h'^2 \sin. {}^2\phi.$$

If it be preferred to substitute v' — the weight in air of 1 foot of cable—and h, the velocity of falling, for v and h', we shall have $v = v' \frac{s' - s}{s}$ and $h' = \frac{h}{tg\, \phi}$, s' being the specific gravity of the cable, and s the specific gravity of the sea-water ; accordingly :

$$v' . \frac{s' - s}{s} \cos. \phi = c . d . h^2 \cos. {}^2\phi.$$

v' is besides $= \frac{\pi}{4} d^2 s'$ multiplied by the weight of 1 cubic foot of water ; accordingly :

$$h = \text{constant.} \sqrt{d\left(\frac{s'}{s} - 1\right)} \frac{1}{\sqrt{\cos \phi}},$$

where s' is found in the constant too.

As ϕ is about 15°, this makes $\dfrac{1}{\sqrt{\cos. \phi}}$ = about 1, and

$$h = c. \sqrt{d\left(\frac{s'}{s} - 1\right)}.$$

By applying this formula on the China-Japan cable we shall have:

$h = 2 \cdot 15'$
d (*diameter of the cable*) $= 0 \cdot 85'$.
s' (*special gravity of cable*) $= 2 \cdot 65$.
s (*specific gravity of sea-water*) $= 1 \cdot 028$.

This makes the constant $= 1 \cdot 9$; Clark states it to be $= 2 \cdot 51$ (see 'Electrical Tables and Formulæ,' p. 150), which latter value makes $h = 2 \cdot 69'$.

A body falling freely through the water will, in the course of a few seconds, move on with uniform velocity (h). Consequently when a cable is payed out from a ship proceeding at a uniform rate, the cable will form a straight line from the ship to the bottom, when there is no tension in the cable at the bottom. Suppose the rate of speed of the ship to be h', then the angle of immersion will be determined by:

$$h' . \textit{tang}. \phi = h.$$

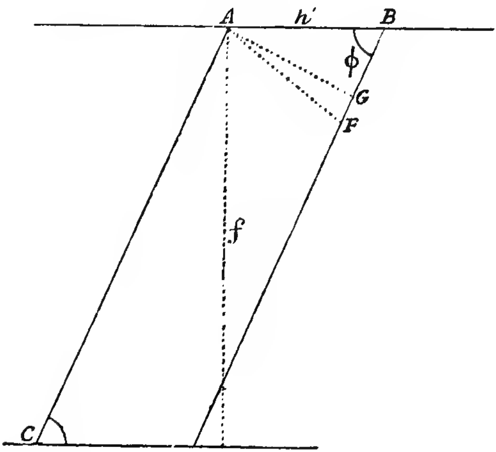
Cable ships have during the paying out sometimes proceeded at 8 knots. This rate, however, is not to be recommended, as it prevents the quick stopping of the ship in case of kinks or breaks occurring in the cable. A speed of 5 to

6 knots will generally be very suitable. Suppose the rate of the ship = $5\frac{1}{2}$ knots per hour, or $h' = 9 \cdot 3'$: then for the China-Japan cable we shall have $9 \cdot 3'$ tang. $\phi = 2 \cdot 15'$ whence the angle of immersion $\phi = 13°$. The angle of immersion is directly as the velocity of sinking, and inversely as the velocity of the ship.

25. STRAIN ON CABLE BY PAYING OUT.

The strain t on the cable during the submersion where the cable enters the water is when there is no tension in the cable at the bottom equal to the longitudinal component of

Fig. 10.



the weight of the cable A C, diminished by the resistance offered by the friction, and this strain has to be counterbalanced by the brake on board the ship.

SUPPOSE:

f = the depth in feet

v = the weight in water of one foot of cable in lbs.

l = the length in feet of A C.

The weight of the cable A C = $v\,l$ and the component along the cable is =

$$v\,l\,sin.\,\phi = v\,l\,.\frac{f}{l} = v\,f$$

The longitudinal velocity of the cable is F G = F B − G B:

Here we have F B, the velocity with which the cable leaves the ship, equal to h, and G B = h' cos. ϕ.

Consequently

$$F\,G = h - h'\,cos.\,\phi.$$

If the friction varies directly as the velocity* the friction of the cable will be

$$= k.\frac{f}{sin.\,\phi}.h'\left(\frac{h}{h'} - cos.\,\phi\right),$$

k being the coefficient of friction.

The strain (t) accordingly will be:

$$t = 0{\cdot}06\,.f\left(v - \frac{k\,.h'\left(\frac{h}{h'} - \cos.\;\phi\right)}{\sin.\;\phi.}\right).$$

where 0·06 is the factor of reduction, when fathoms (6′) and hundredweights (100 lbs. = cwt.) are used.

* W. Siemens, p. 46 and p. 126 in 'The Journal of the Society of Telegraph Engineers,' 1877.

EXAMPLE. The China Japan cable.

f = depth of water in fathoms = 100

v = weight in water of 1 foot of cable = 0·4 lbs. (1·09 tons per knot).

h = velocity, with which cable leaves ship = 9·5′ per second.

h' = rate of the ship = 5½ knots per hour = 9·3′ per second.

ϕ = angle of immersion = 13°.

k = coefficient of friction = 0·007 diameter of cable = 0·006, 0·85.

$$t = 0{\cdot}06\,.\,100\left(0{\cdot}4 - \frac{0{\cdot}006\,.\,9{\cdot}3\left(\frac{9{\cdot}5}{9{\cdot}3} - \cos.\ 13^{\circ}\right)}{\sin.\ 13^{\circ}}\right).$$

$$t = 6\,.\,(0{\cdot}4 - 0{\cdot}012) = 2{\cdot}33 \text{ cwt.}$$

This strain, however, may increase by the inertia of the paying-out drum to 10 cwt., when the ship is rolling in heavy weather.

When the ship remains stationary, that is $h = 0$, the strain t will be $0 \cdot 06\,fv$—or equal to the weight (in hundred-weights) of the cable, the latter supposed to hang vertically from the ship to the bottom. This maximum strain may too be approximately obtained, when the cable is payed out without slack.

The formulæ shows that the strain on the cable is in direct ratio of the *specific gravity* of the cable or of the weight of a piece of cable hanging vertically from the ship to the bottom of the sea, consequently a lighter cable gives a smaller tension. The strain is in inverse ration of *the angle of immersion*, consequently by reducing the angle of immer-

sion (as by giving the ship greater speed) the strain will increase, and the cable is likely to break; by increasing the angle the strain is diminished, causing a superfluous amount of slack and possibly kinks in the cable.

The *strain* is *used* partly *to* overcome the resistance of the water against the sinking of the cable, partly to lay the cable without tension on the bottom of the sea. *The excess of strain* being counterbalanced by the brake, the force of which increases with the depth, the depth may be determined from the brake force.

The *slack* is directly proportional to the amount with which the weight of the cable hanging vertically surpasses the brake force, and inversely proportional to the square of the velocity of the ship.

To ascertain if *a proper slack* is payed out, the strain on the dynamometer may be increased with 1 cwt., and if it has no effect upon the number of revolutions of the paying-out drum, then it is pretty sure that unnecessary slack is not being payed out.

26. ORGANIZATION OF CABLE STAFF.

The staff required during the paying out ought to be in two parties, each consisting of:—	Chief Engineers.	Electricians.	Foremen.	Men.
In the testing-room	—	2	—	—
At indicator	—	1	—	—
„ dynamometer	—	—	1	—
„ jockey wheels	—	—	—	1
„ stern pulley	—	—	—	2
In the tank	—	—	2	7
Making for one watch	—	3	3	10
And for two watches	—	6	6	20
Besides:				
The chief engineer	1	—	—	—
A jointer	—	—	1	—
A man in the testing-room ..	—	—	1	—
„ „ store-room ..	—	—	1	—
Total	1	6	9	20

One of the two foremen at the dynamometer should be a ship-carpenter, and the other a mechanician.

APPENDICES.

APPENDIX I.

COILING OF CABLE ON BOARD.

1. The coiling has to be performed simultaneously in as many tanks as possible.

2. Water is to be kept up in the tanks to the working flake.

3. When the coiling in a tank is completed, the tank is to be immediately decked over safely in the usual manner.

4. During coiling a foreman shall be in every tank. The Company will during coiling always keep an Engineer on board the ship.

5. The foremen are to give notice to the Company's Engineer, when any defective places in the outer covering show themselves, so that these places may be repaired.

6. During coiling, the cable is, if required, to be provided with new thin leather milemarks, and the old ones removed in the factory tanks.

Over the second flake payed into the tank two strips of oilcloth are to be placed as a mark. At every bottom-end a length of 40 fathoms has to be left out for splicing.

7. The foremen are to inform the Company's Engineer when a splice is passing the indicator, and the number of revolutions is then to be noted.

8. During coiling every flake of the cable is to be thoroughly whitewashed and every splice to be painted red.

9. The cables are to be measured on an indicator, being coiled at least twice round the indicator-wheel. Should this not be possible with the shore-end cables, these cables are to be measured with a jockey-wheel under the necessary precautions.

10. The contractor's Engineer will inform the Company's Engi-

neer of the number of flakes and the number of turns in the undermost and the uppormost flake of cable in each tank.

11. When the coiling of a cable is about to be finished, and before the cable-end leaves the indicator, the foreman has to inform the Company's Engineer, in order that the length of the cable may be accurately measured.

12. Immediately before a cable is coiled on board, and immediately after it has been coiled on board, a test is to be taken by the Electricians of the Company and of the contractor.

13. So long as the cable is being coiled on board the ship, a continuity and insulation test is to be taken on shore.

14. Once a day all cables on shore and on board ship are to be tested by the Company's and the contractor's Electricians.

15. Duplicate sheets of tests, taken by the contractor's Electricians, are to be handed to the Company, who will keep the necessary journals on board ship.

APPENDIX

Records of coiling.

Tank

Station No. ,

FACTORY LENGTH OF THE SECTION:

Date.	Number of Flake.	Number of Turns in Flake.	Mile Marks.		Splice.	
			Number of Turns.	Number of Miles.	Number of Revolutions.	Length of Cable in Knots.

II.

No. .

Cable No. .

REVOLUTIONS OF THE INDICATOR PER KNOT:

Signature.	Remarks.

Journal a. APPENDIX

Date.	Length of Cable in Knots.	Temperature.	Indicated Resistance of Leading Wire.	Indicated Resistance of Cable-end Wire.	Real Resistance of Cable.	Total Resistance at 75° F.	Resistance per Knot at 75° F.	Specific Conductivity.	Resistance of Galvanometer.	Cable Shunt.	Deflection u' after 1m. charge + 1m. Ins.	Deflection u after 1m. charge.	Percentage of loss of charge after 1m.
	1	2	3	4	5	6	7	8	9	10	11	12	13

III.

Condenser Shunt.	Deflection from Condenser.	Total Charge of Cable.	Charge of Cable per Knot.	Shunt of Battery.	Constant n of Battery.	Shunt v' of Galvanometer.	Constant ϕ of Galvanometer.	Shunt v at Cable.	Deflection after 1m.	Deflection after 2m.	Total Insulation.	Insulation per Knot.	Insulation per Knot at 75° F.	REMARKS.
14	15	16	17	18	19	20	21	22	23	24	25	26	27	

APPENDIX

Journal b.

Tank.

Section No.

Date.	Copper-resistance in Ohms.		Insulation in Megohms.		Inductive Capacity in Microfarads.
	Total at 75°.	Per Knot at 75°.	Total at 75°.	Per Knot at 75°.	

IV.

No.

Cable No.

Loss of Charge after 1^m Insl.	Temperature.		Signature.	Remarks.
	Tank.	Air.		

APPENDIX V*a*.

INSTRUCTIONS TO ELECTRICIANS.

1. The Electrician is subordinate to the Superintendent of the station, and he performs the whole of his service under the responsibility and superintendence of the latter; when assisting at repairs of cables, however, he will chiefly have to attend to the direct orders from the Engineer in charge of the repairs.

His reports are forwarded to the Board by the Superintendent, through whom too he receives the orders of the Board.

2. *The Duties of the Electrician are:*

To perform the duty of a telegraph clerk in the station.

To take care of the instruments, batteries, etc., belonging to the station.

To keep account of the store of the station.

To make regular tests of the cables and land-lines belonging to the Company, and

To assist in case of interruptions.

3. The Electrician ought to have a thorough knowledge of the *apparatus* as regards their theory as well as their mechanical construction, that he may be able to correct the minor faults himself, and control the repairs when these are made by the instrument-maker or other mechanic on the spot. He cleans the apparatus every day, and once a week he tests the resistance of it by sending a current through a galvanometer and apparatus to earth.

He examines and cleans the connections of the instruments and lightning protectors.

Once a month he examines the instruments thoroughly, separating the parts and removing dust, rust, etc.

4. Every day he ascertains the electro-motive force of the whole

battery by means of a galvanoscope, and, if found necessary, the power of each single cell.

As often as required—at least once a month—he cleans the connections of the battery, and charges the elements according to the printed directions for the maintenance of the battery: App. V*b*.

He sees that no greater battery power is used for the working of the line than required by the apparatus of the receiving station.

5. It is desirable that the Electrician should be able to make a temporary *joint in insulated wire.*

A direction for making joints in guttapercha core as well as in indiarubber will be found in App. V*c*.

6. He sees that the necessary *spare things* are always at hand as well for the instruments in the station as for the land line, and, as far as possible, for the cables too.

He sees that all the instruments and batteries are in perfect working order. This applies to the spare instruments and spare batteries as well.

7. He keeps *an account* of all the stores, and all deliveries to and from the same are made through him.

8. Once or oftener every month he *takes regular electrical tests* of the Company's cables in accordance with the established "Instructions:" App. V*d. or* V*e.*

9. In case of *interruption* of the line he has to make all requisite electrical tests in accordance with the "Instructions:" App. V*f.*

10. When the *fault* is found to be in the cable he should be in the cable-house as soon as possible, and not later than 10 o'clock in the morning after the interruption has taken place, and there try to determine the position of the fault.

From 9 p.m. till 6 a.m. the cable end is kept well insulated. He remains at the cable-house until the cable has been repaired, and he receives the necessary assistance from the staff of telegraphists in the station.

APPENDIX V*b*.

MOUNTING AND MAINTENANCE OF THE LECLANCHÉ BATTERY.

1. The Leclanché cells are made in three sizes, viz.: No. 1, small; No. 2, middle-sized; and No. 3, large.

2. The carbon plates are placed in the centre of the earthen cells, and the space around them slowly filled up with needled manganese (peroxide of manganese crushed, mixed with an equal volume of horn carbon crushed, both carefully sifted and free from dust). This mixture should be stamped slightly with a wooden pin.

3. The zinc plates are amalgamated in the usual way, care being taken to prevent the quicksilver from reaching the point where the copper band comes in contact with the zinc.

4. The glass jar is half filled with a saturated solution of sal-ammoniac.

When the battery becomes weakened, a fresh supply of the solution may be added up to three quarters of the height of the glass. If it is intended to be used as a portable battery, the jars should be filled with sawdust before pouring in solution.

5. To prevent the crystallization of salts, which weakens the action of the cells, it is necessary to keep the upper part of the glass jar, rising above the surface of the fluid, perfectly dry; on board cable-ships, for instance, the glass jar should always be paraffined, and in filling the glasses, care should be taken to prevent the fluid from running down the sides of the jar, which may be avoided by pouring the fluid through a glass funnel with a long tube.

Should any formation of crystals take place in spite of these precautions, the crystals must be scraped off carefully whenever an opportunity presents itself.

6. The cells should be charged and put on short circuit a few hours before being used.

7. When the cells are unmounted for cleaning, it will generally be necessary to break the porous cells to get out the carbons; this should be done with great care, however, otherwise the carbons are likely to get damaged also.

The zinc is scraped clean with a knife, and amalgamated anew. The other parts of the cell are cleaned with a brush and cold water. If necessary, the copper band should be coated with Brunswick black or Clark's compound.

APPENDIX V*c*.

DIRECTIONS FOR MAKING JOINTS.

Care must be taken to keep the hands, tools and materials, clean and dry.

A. MAKING A JOINT IN GUTTAPERCHA CORE.

1. Remove the guttapercha for 2½ inches from each end of the conductor, and clean the latter carefully with emery paper.

2. *a. The conductor to be soldered by a scarf joint.*

Put the chloride of zinc on the end of the conductor, and apply the solder, which should be melted on a strongly heated copper bolt. The soldering fluid used consists of one part of muriatic acid, saturated with zinc, and diluted in three parts of water.

The solder should be soft, and composed of bismuth, zinc, and tin.

Having soldered each end so as to form a solid to within ¼ of an inch of the guttapercha, smooth them carefully, and file and scarf the ends down for 1 inch, so as to make the surfaces fit together; place the ends together in a vice, solder them, and then serve them with No. 28 wire, laid on tightly, four ply at a time.

Solder again, filling up the space between the turns with solder in order to keep them close to the conductor, and finally put on another serving of single No. 28 wire in an opposite direction to the first serving, but solder at the ends only.

2. *b. The conductor to be soldered by a twisted joint.*

The guttapercha having been removed for $2\frac{1}{2}$ inches, serve the conductor for $1\frac{1}{4}$ inch, beginning at the guttapercha, with copper wire No. 28, thus preventing the strain from opening.

Straighten the single wires—they are generally seven in number—and having cut off the central one $1\frac{1}{4}$ inch from the end, interjoin the remaining six with the six wires of the other end, which has been prepared in the same manner. Twist the six wires evenly and tightly around the other conductor, solder and file down all projecting points.

For cable repairs the twisted joint is preferable, when time is an object.

3. Having finished the soldering, put on a layer of Chatterton's compound, which should be spread evenly with a hot iron and tooled down to reach the ends of the guttapercha.

4. Heat the guttapercha core at both ends over a spirit-lamp, until it becomes soft and pliable, then draw it over the layer of compound, and smoothen the guttapercha with a hot iron.

The spirit lamp has to be used with the greatest caution, so that the guttapercha is not burned, nor the oil it contains evaporated by over-heating.

5. Apply a second layer of Chatterton's compound, and spread it evenly and smoothly to cover about 1 inch of the original guttapercha coating.

6. Apply another layer of guttapercha and tool it down to cover one inch of the previous layer.

7. Finally, lay on another layer of the compound, smooth down the joint, and cool it in cold water, after which an insulation test is made in the usual way. (Three coatings are often used, especially if it is a large sized core.)

B. MAKING A JOINT IN INDIARUBBER CORE.

1. Fasten the core between two vices, and remove the felt for 12 inches from each end of the core by soaking the felt with mineral naphtha, and then rubbing it off clean with carding.

2. Cut off $2\frac{1}{2}$ inches of the indiarubber and solder in the same manner as for guttapercha core, only using rosin instead of chloride of zinc.

By using solving fluid the operation of soldering is rendered easier, but as indiarubber suffers when heated in a greater degree than guttapercha, and as the fluid attacks indiarubber, rosin should be used in preference.

3. Sear the surface of the indiarubber with a red-hot iron for 3 inches on each side of the conductor joint.

4. Clean well the seared parts with the glazed side of small calico squares moistened with mineral naphtha so as to leave a clean adhesive surface.

5. Taper the insulator down to the conductor about 2 inches on each side of the conductor joint with a pair of curved scissors, so as to make the pure indiarubber layer visible for at least $\frac{1}{4}$ of an inch.

6. Coat the conductor with pure rubber tape lightly laid on in a spiral form, commencing at the spot where the separator ends across to the corresponding place on the opposite side of the joint, and back again in an opposite direction. The ends are fastened down by pressing a clean heated knife on them, or applying a little mineral naphtha.

7. Lay on lightly the white separator tape in the same way, but beginning where the jacket or outer layer of vulcanized rubber ends. One lap of this will be sufficient.

8. Complete the insulation by lapping on tightly two layers of red tape (vulcanized rubber); the last layer must cover each end of the core for 3 inches on each side of the conductor joint or to the extent of the searing.

9. Lay on tightly three bindings of calico tapes, all in the same direction, and fasten the ends with indiarubber cement.

10. Immerse the joint in the jointing bath at 150° to 200° Fahr., and gradually raise the heat, so that in a quarter of an hour the temperature will be 310° Fahr., at which temperature keep the joint for another fifteen minutes, then take it out, and let it cool in the open air.

Two of the outer layers of calico which have been penetrated with wax in the bath are removed before the joint is tested, and having completed the insulation test, the joint is coated with felt.

APPENDIX V*d*.

INSTRUCTIONS FOR TESTING GREAT NORTHERN TELEGRAPH COMPANY'S LINES.

1. *Regular electrical tests are made on Sunday morning once or oftener every month.*

2. The tests are made *at an hour*, which in this paragraph is fixed for each of the cable stations, viz.: Aberdeen, Newcastle, Calais, Söndervig, Hirtshals, Gothenborg, Rönne, Libau, Nystad, Wladiwostock, Nagasaki, Gutzlaff, Woosung, Amoy, and Hongkong.

3. The Electrician in the cable house nearest Copenhagen or Shanghai orders the other end of the cable to be put *to earth* for thirty minutes, during which time he measures the copper-resistance of the cable. No more than ten cells must be used for this test, except where strong earth-currents are observed. In case of earth-currents the deflection made on the scale without shunting should be noted down, and whether positive or negative.

Having completed this test, he orders the same end to be *insulated* for thirty minutes, dividing this time equally between the insulation test and the test for the electrostatic capacity of the cable. As few cells as possible are used, never more than twenty-five.

If he deems it necessary, he may repeat the tests, unless there is an Electrician at the other end of the cable, in which case the latter will have to take a similar series of tests.

When a cable is connected with a *land-line* the resistance and insulation of this should be tested. For this purpose the Electrician orders the end of the wire to be put to earth for ten minutes, during which time he measures the resistance of the wire; and to be insulated for another ten minutes, during which he measures the insulation.

This test may be taken from the cable station, while the cable

end is put to earth for thirty minutes, and the cable tested from the cable station at the other cable end.

4. The tests must not take more than *two hours.*

5. When the *core* has to be *insulated* the hemp and iron-covering should be removed for 18 inches, and having rubbed off the felt from the core for 6 inches, 1 inch of the copper conductor should be deprived of the insulating material, and left quite bare.

Finally, to be certain of good insulation, ½ inch of the copper near the insulator and 1 inch of the latter should be coated with paraffine wax, and then suspended freely in the air.

6. As soon as *the tests are finished,* the terminal telegraph stations are informed, and the cable is again connected with the land-line through the lightning guard.

The *results of the test* are entered in a journal of the form given in Appendix V*e.*, of which a copy is forwarded as soon as possible after the test, and a telegram sent at once stating only the average number in ohms of the copper-resistance, with zinc and copper, and the insulation per knot after the first minute, for instance: 2320 ohms, 3210 ohms, 1020 megohms.

7. When the communication through the cable is still uninterrupted, but *a fault* has shown itself, having a resistance less than 10,000 ohms, tests should be taken every Sunday.

The results of the test are entered in a journal (for the form, see Appendix V*f.*), a copy of which has to be forwarded as soon as possible after the test, and a telegram sent at once, stating only the copper-resistance, when the cable is put to earth or when it is insulated and the insulation per knot after the first minute—for instance: 2200 ohms, 10,500 ohms, 4 megohms.

8. When the *communication is interrupted,* the Electrician must immediately examine the instruments and connecting wires, to ascertain that the interruption is not in the station, and having done this, he takes a test of the land-line, and if the fault is found here, he must try to get it repaired as soon as possible, at the same time reporting the position of the fault to the Superintendent of the station.

When the interruption proves to be in the cable itself, he must at once proceed to the cable house in order to be there as soon as possible, and not later than at 8 o'clock A.M. the day after the interruption has taken place; there he tries to determine the distance of the break by a series of careful tests taken in the following way:—

THE STATION NEAREST COPENHAGEN OR SHANGHAI.	THE OTHER TERMINAL STATION.
From 10–12 *o'clock.*	
Measurements of earth currents, insulation, capacity and copper-resistance.	End of the cable insulated.
From 12–1 *o'clock.*	
Measurement of earth currents and copper-resistance.	End of cable insulated.
From 1–1½ *o'clock.*	
Currents reversed every second minute sent into the cable.	End of cable through galvanometer to earth.
From 1½–2 *o'clock.*	
End of cable through galvanometer to earth.	Currents reversed every second minute sent into the cable.

From 2–3 *o'clock.* If by the previous test any communication has been observed between the stations, a copper current is sent into the cable for fifteen minutes, and if speaking is possible, the first communication sent through should be the result of the copper test.

From 3–5 *o'clock.*	
End of cable insulated.	Measurement of earth currents, insulation, capacity and copper-resistance.
From 5–6 *o'clock.*	
End of cable to earth.	Measurement of earth current and copper-resistance.

The test is repeated the next day from 10 A.M. to 6 P.M., and every following day from 10 to 11, while the end of the cable is put to earth through the galvanometer from 6 A.M. till 9 P.M., and kept insulated from 9 P.M. till 6 A.M.

As soon as the galvanometer indicates that current is being sent

through the cable, the instruments are joined up for speaking, and the call from the ship is awaited.

The results of the tests are entered in a journal (see App. V*f.*), a copy of which is forwarded to the Board; but the telegram sent immediately after the test only states: (1) The average numbers in ohms of the copper-resistance by zinc and copper, found by at least twenty quick reversals of zinc and copper; (2) the temperature of the sea; (3) the supposed distance of the break from the testing station; thus the report despatched would be, for instance, 2130 ohms, 70 degrees, 505 knots.

NOTES.

1. The mean resistance R_2 is found by at least 10 readings with quick reversals of zinc and copper.

2. Temperature of the cable $= \left(75^\circ - \frac{R - R_2}{0 \cdot 0021 \times R}\right)^\circ$ Fah.

3. If when measuring the earth current a shunt has been used, the entry made should state the actual deflection multiplied by the value of the shunt (or the multiplying power of the shunt).

4. The percentage of loss of charge is $= \frac{u - u'}{u} \times 100$.

5. The insulation per knot found by loss of charge is $= \frac{0 \cdot 4343 \times 60}{C \log. \frac{u}{u'}}$ meghoms.

6. The insulation per knot is $= \frac{n v' \phi R^1 l}{v U'}$. By using a sufficiently great resistance R', the deflection ϕ of the galvanometer may be determined by using the whole battery, and the constant n is made superfluous.

7. The insulation of the land line is most readily found n the same manner as the copper-resistance, viz., by using the Wheatstone's bridge.

APPENDIX *Ve.*

JOURNAL

FOR

ORDINARY TESTS

OF

The cable from ____________________

to ____________________

____________________ Station.

____________________ 18__

Tests taken by

____

Date.	Copper-resistance.						Earth Current.		Electrostatic Capacity.					
	Length of the Cable l, in knots.	Copper-resistance R at 75° F.	Resistance with Zinc Current.	Resistance with Copper Current.	Mean Resistance R_1.	Temperature of Cable in ° F.	Positive Deflection.	Negative Deflection.	Inductive Capacity C per Knot.	Deflection from Condenser.	Cable Shunt.	Deflection u by instantaneous Discharge.	Deflection u' after 1 minute's Insulation.	Percentage of Loss of Charge.

Insulation.												Land Line.		Temperature.			Remarks.
Insulation found by Loss of Charge.	Number of Cells used.	Constant n of the Battery.	Galvanometer Shunt v'.	Resistance R' in Megohms.	Constant of Galvanometer ϕ.	Cable shunt v.	Deflection U' from Cable after 1st minute.	Deflection U' from Cable after 2nd minute.	Deflection U' from Cable after 5th minute.	Insulation per Knot after 1st minute.	Insulation per Knot at 75° F.	Copper-resistance per Knot.	Insulation per Knot.	Temperature of the Air in ° F.	Temperature of the Water in ° F.	State of Barometer.	

APPENDIX V *f*.

JOURNAL

FOR

TESTS ON INTERRUPTION

OF

COMMUNICATION

Cable from ________________________

To ________________________

____________________ Station.

____________________ 18__

Tests taken by

____

NOTES.

1. In case of a fault the distance y is determined by Blavier's method, according to which

$$y = R_2 - \sqrt{(R - R_2)(R_1 - R_2)}$$

In case of a break the distance is calculated by the copper-resistance.

2. If when measuring the earth current a shunt has been used, the entry made should state the actual deflection multiplied by the value of the shunt (or the multiplying power of the shunt).

3. The percentage of loss of charge is $= \frac{u - u'}{u} \times 100$.

4. The insulation per knot found by loss of charge is $= \frac{0 \cdot 4343 \times 60}{C \log. \frac{u}{u'}}$ megohms.

5. The insulation per knot is $= \frac{n\, v'\, \phi\, R^1\, l}{v\, U'}$. By using a sufficiently great resistance R′ the deflection ϕ of the galvanometer may be determined by using the whole battery, and the constant n is made superfluous.

6. The insulation of the land line is most readily found in the same manner as the copper-resistance, viz., by using the Wheatstone's bridge.

Date.	Copper-resistance.						Earth Current.		Electrostatic Capacity.						
	Length of Cable l, in Knots.	Resistance R of the faultless Cable.	Resistance R_1 when Cable insulated.	Resistance R_2 when Cable to earth.	Distance of fault found by Blavier's method.	Distance of fault found by Copper-resistance.	Positive Deflection.	Negative Deflection.	Induct. capacity C per Knot.	Deflection from Condenser.	Cable Shunt.	Deflection u by instantaneous Discharge.	Deflection u' after 1 minute's Insulation.	Percentage of Loss of Charge.	Distance of Fault determined by Discharge.

Insulation.											Land Line.		Temperature.			Remarks.
Number of Cells.	Constant n of the Battery.	Galvanometer Shunt v'.	Resistance R' in Megohms.	Constant of Galvanometer Φ.	Cable Shunt v.	Deflection U′ from Cable after 1st minute.	Deflection U′ from Cable after 2nd minute.	Deflection U′ from Cable after 5th minute.	Insulation per Knot after 1st minute.	Insulation per Knot at 75° F.	Copper-resistance per Knot.	Insulation per Knot.	Temperature of the Air in ° F.	Temperature of the Water in ° F.	State of Barometer.	

APPENDIX VI.

Log a.

Paying out from Tank.	Cable.	
Date		
Ship's time, longitude and latitude		
Ditto, by observation		
Distance by patent log		
Ditto by ship's log in every two hours		
Depth of water, and nature of bottom		
Revolutions of screw per minute		
Time		
Revolutions of drum per minute		
Total revolutions		
Total length payed out		
Knots payed out in the last hour		
Average strain on dynamometer		
Temperature of air		
Ditto of tank		
Ditto of sea water		
Names of men at brakes		
Ditto of foremen in tanks		
Signature		
General remarks, as: orders given, ships passing, stoppages, and everything, however trifling, affecting the cable-laying.		

Log b.

APPENDIX

Time.	Cable.	Revolutions of drum per minute.	Revolutions of screw per minute.	Strain on Dynamometer.	Total number of revolutions	Total length of cable payed out.	Length payed out in the last hour.

VII.

GENERAL REMARKS. Ship's time, longitude and latitude; distance by observation, by patent log and by ship's log; depth of water and nature of bottom; change in revolutions of screw, orders given, stoppages, ships passing, and everything, however trifling, affecting the cable-laying.	Signature.

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